PREDICTION OF GRINDING MACHINABILITY WHEN GRIND ALUMINIUM ALLOY USING WATER BASED COOLANT

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ABSTRACT

Optimization of parameters for the surface quality of material is very important for this research because of higher demands for surface finishing products especially in the manufacturing process. More researchers have tried various methods in order to reduce production cost and to produce very economical machining process. One of the most common machines in the finishing process of the product is grinding machine. For this thesis, the present study involves prediction of grinding machine when grinds aluminium using water based coolant. This thesis has been run to find optimum parameters such as wheel wear and depth of cut. Different number of passes which are single pass and multi pass with different parameters will be studied and compared. Another objective of this thesis is to investigate surface roughness produced during grinding process. Prediction model of surface roughness was developed to present accurate data. The selected material for this study was Aluminium Alloy 6061 T6 and was used water based coolant as cooling lubrication. Experiments were conducted based on Design of Experiment (DOE) and the Neural Network is employed to find optimum parameters and predicted of surface roughness and wheel wear for the selected material. These experiments were divided into two by using two different grinders which are aluminium oxide and silicon carbide. The surface roughness was measured at every increment of 2µm depth of cut. The results have found that the surface roughness increased when the depth of cut increased while the surface roughness decreased when number of passes increased. Besides, the surface quality becomes smoother when using Aluminium Carbide as grinder compared to Silicon Carbide.

ABSTRAK

Pengoptimuman parameter untuk kualiti permukaan bahan produk adalah sangat penting untuk kajian ini kerana permintaan yang lebih tinggi bagi kemasan permukaan produk terutamanya di dalam proses pembuatan.Pada masa dahulu, ramai penyelidik telah mencuba pelbagai kaedah untuk mengurangkan kos pengeluaran dan menghasilkan proses pemesinan yang menjimatkan.Salah satu mesin yang biasa digunakan bagi proses kemasan produk ialah mesin pemipisan. Kajian ini melibatkan ramalan pengisaran pemesinan apabila mengisar aluminium alloy menggunakan penyejuk berasaskan air. Tesis ini telah dijalankan untuk mencari parameter yang optimum seperti kelajuan, diameter dan kedalaman pemotongan. Jumlah laluan pemipisan dengan parameter yang berbeza akan dikaji dan dibandingkan. Objektif yang lain untuk tesis ini adalah untuk menyiasat jenis kekasaran, suhu permukaan, dan memakai dihasilkan semasa eksperimen. Model ramalan kekasaran permukaan telah dibangunkan untuk mempersembahkan data. Bahan yang dipilih untuk kajian ini adalah Aluminium Aloi 6061 T6 dan penyejuk berasaskan air digunakan sebagai pelinciran. Eksperimen telah dijalankan berdasarkan Reka bentuk Eksperimen (DOE) dan Rangkaian Neural digunakan untuk mencari parameter yang optimum dan menganalisis kesan parameter terhadap kekasaran permukaan untuk bahan yang dipilih. Eksperimen ini telah dibahagikan kepada dua dengan menggunakan dua pemipis yang berbeza iaitu Aluminium Oksida dan Silikon Karbida. Kekasaran permukaan diukur pada setiap peningkatan kedalaman 2μm potongan.Keputusan telah menunjukkan bahawa kekasaran permukaan meningkat apabila kedalaman pemotongan meningkat manakala kekasaran permukaan menurun apabila jumlah laluan pemipisan meningkat. Selain itu, kualiti permukaan menjadi licin apabila menggunakan Aluminium Oksida sebagai pemipis berbanding dengan Silikon Karbida.

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LIST OF ABBREVIATIONS

AA	Aluminium Alloy
r	R-squared
n	Total number depth of cut
x	Depth of cut
y	Surface roughness or wheel wears results
MSE	Mean Square Error
MAPE	Mean Absolute Percentage Error
MAD	Mean Absolute Deviation
	Actual value
	Predicted value
Si	Silicon
Cu	Copper
Mn	Manganese
Mg	Magnesium
Cr	Chromium
Zn	Zinc
Ti	Titanium
Fe	Iron
HP	Horse Power
RPM	Revolution per Minute
ANN	Artificial Neural Network
Ra	Surface roughness
SiC	Silicon Carbide
Al_2O_3	Aluminium Oxide
ZnO	Zinc Oxide
AE	Absolute Error
ARE	Absolute Relative Error

TRN	Training
TST	Testing
VLD	Validation

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Nowadays, more researcher in modern machining industries is mainly focused on the achievement of high quality, in terms of work piece surface finish or less wear on cutting tools, and also the economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact.

Besides that, the quality of any products is depending on surface roughness because the increase of surface roughness will cause the quality product also decrease. Surface roughness and wear are important roles in many areas and factors of great importance the evaluation of machining accuracy. In this scenario, the grinding process was chosen for this project to get optimum parameters. There has been high demand for better adequacy of industrial grinding process in order to meet the present requirements of standardization and safety.

The selection of material type also needed in this project. Aluminum Alloy 6061 T6 was used as the work piece for this project. The main reasons are because the aluminium alloys are extensively used in engineering structures and have many properties of behaviour and several type series in the world which are 1xxx until 7xxx series.

1.2 PROBLEM STATEMENT

The findings of optimum parameters in grinding process are very important due to challenges in modern machine nowadays especially in terms of surface quality and also low cost manufacturing. Besides that, the effect of coolant very important in order to reduce surface cracking and subsurface damage and to prevent high temperature occurs during grinding process. This need to avoid ensuring that good surface quality was produced. Therefore, water based coolant is using to see the consequences. The suitable depth of cut is also needed because it can affect the surface texture have been rougher and the surface is not shining. The results of the experiment must consider in different perspective of the parameter to get accurate results.

1.3 OBJECTIVES

From the discussion above, this project has set three objectives:

1. To find the optimum parameters of grinding process (depth of cut).
2. To investigate surface roughness produced during grinding process.
3. To develop prediction model of surface roughness using artificial neural network.

1.4 SCOPE OF STUDY

In the present study, the grinding parameters and variables will be considered is the depth of cut (μm), number of passes of (n), abrasives material and type of coolant. Table speed is set as constant for the whole experiments with 200 RPM. Two abrasive materials which are silicon carbide and aluminium oxide were used as a grinding wheel. Eighteen number experiments will be conducted for every single pass and multi-passes grinding. A range of thirty six experiments will be expected to be running on the aluminium alloy. The surface roughness of different number of passes and abrasives material with different depth of cut will be studied and compared.

In analyzing the data in this project, it will see based on the surface roughness and wear produced by adjusting the parameters of the material example depth of cut and number of passes when using water based coolant.

After finishing conduct all experiments, all the data will be gathered and will be plotted in a graph based on data obtained. The results will be analyzed by using neural network software. Then, the results will be interpreted to state the discussion, conclusion and to summarize the objective of the project.

1.5 THESIS ONLINES

This present study is organized into five chapters. The first chapter has been discussing the project background, problem statement, objectives, and also the scope of the work of this project. Chapter two discussed the literature review of the project. It focused on recent studies that approximately close to the titles. The literature reviews very important to predict the result for the project based on the previous results and knowledge from the journals, books and internet. Chapter three represents the research methodology, design of experiments and application tools have been used in this present study. Chapter four represents the result of this project and then discussion of the overall result based on all data obtained. This present study will summarize in chapter five.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the background of grinding machine, response surface method and aluminium alloy. This chapter also will focus on recent studies or research by authors related to the effect of grinding process parameters on surface roughness, temperature and wear of aluminium alloy or approximately close to the titles of the project.

2.2 THE GRINDING PROCESS

Almost every manufacturing process requires a final machining process in order to get smooth surface and fine tolerances. Thus, grinding process is very important in the manufacturing process because it plays as sharpen cutting tools for drilling, turning and milling. The objective of a grinding process is to remove material as quickly and efficiently as possible with little concern for surface quality (S. Malking and C.Guo, 2008). Grinding also is a finishing machining or operations by removing a small amount of material during the process. Grinding used to improve surface finish for any shape and geometry of hard material (E. Mehmood, n.d).

One of the advantages the grinding process is it becomes more economical as a single process for machining directly to the final dimensions without the need for prior turning and milling.

The most common of the grinding process is surface grinding process even though there are many types of grinding in manufacturing and machining industry. The grinding process is very important because it can produce surface finishes from rough to extremely fine. The surface grinding machine also used for grinding flat surfaces as we can see in the figure below. The specification of surface grinding machine is it has a magnetic table to place the work piece.

In grinding machine, the speed of power driven grinding wheel is determined by wheel's diameter. Work piece stays in fixed position and machine vice required to hold the work piece tightly. Only the machine table will move right and left during the grinding process. Coolant tube is used to provide water- based coolant when operation is running (T.J. Vickerstaff, 1973).

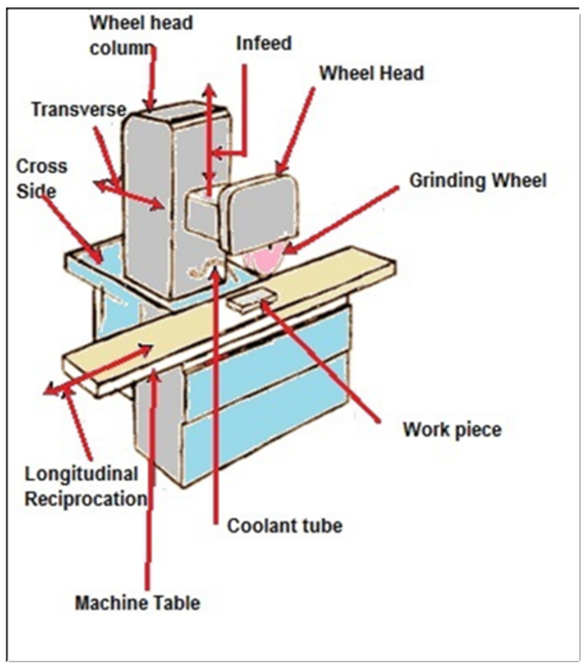

Figure 2.1: Surface Grinding Machine used in the present study

From the research, grinding machines can be classified as utility grinding machines, cylindrical grinding machines and surface grinding machines. Surface grinding machines generally have horizontal wheel spindles and mount straight or cylinder-type grinding abrasive wheels. From the Figure 2.1, we also can see that the work piece is supported on a rectangular table which moves back and forth and reciprocates beneath the grinding wheel. The function of coolant tube is to drain the coolant during the machining. It also can reduce excessive friction between work piece surface and grinding wheel.

S. Kalpakjian (n.d) mentioned that grinding machines are used for cutting off steel, especially tubes, structural shapes, and hard metals. In grinding operations, grinding users can choose two techniques in grinding whether to use single-passes grinding and multi-passes grinding. A grinding wheel with a large grit size result in a large damage depth to the ground work piece in single-pass grinding while in multi-pass grinding, machine stiffness becomes less important than in a single pass grinding in terms of stock removal rate and wheel (B. Zhang, et al., 1999).

2.2.1 Specification of Surface Grinding Machine

Surface grinding is the act of producing and finishing flat surfaces by means of a grinding machine employing a revolving abrasive head. The maximum speed of surface grinding machine is 2800 RPM. It also has a magnetic table to place the work piece. The cylindrical shaped job can't be machined by this grinding machine, but only flat jobs can be machined.

The reciprocating surface grinding machine is a horizontal type surface grinding machine. The work pieces are fastened to the work piece table. It can be moved beneath the grinding abrasive wheel by hand or power feed. A magnetic chuck may be used for fastening the workpiece to the table (Figure 2.2).

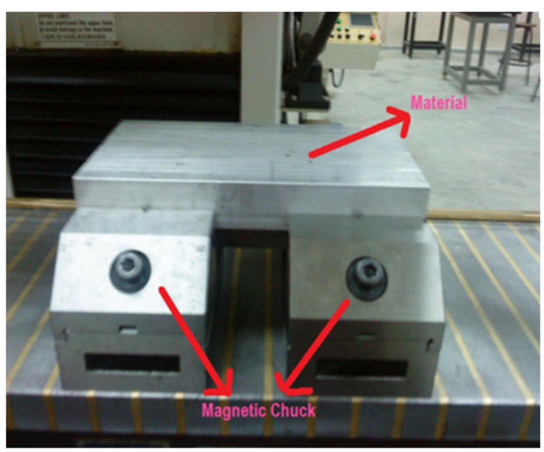

Figure 2.2: Magnetic chuck

2.2.2 Horizontal Grinding Machine

The society today has more advantages compared to old society in manufacturing process fields. Old society using traditional machines to get the best and smooth surface finish of any materials and products. But today, due to technology development, the modern machines such as milling, turning, drilling, and others have used in the manufacturing process. A horizontal grinding machine also always used as we can see in Figure 2.3.

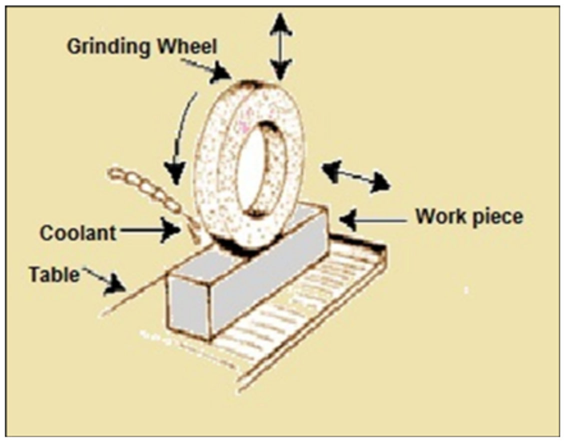

Figure 2.3: Horizontal Grinding Machines

Horizontal surface grinding used in tool making work of small production work to large sizes used production work. It also ranges from small capacity (S. Kalpakjian, n.d).

2.2.3 Grinding Wheel

S. Malking and C. Guo (2008) stated that the abrasive materials of greatest commercial importance are included aluminium oxide (Al_2O_3), silicon carbide (SiC), cubic boron nitride (cBN) and diamond. Aluminium oxide with 2100 relative hardness used to grind steel and other ferrous and high-strength alloys. SiC is harder than Al_2O_3, but not as tough and the value of hardness is 2500. It also cannot be used effectively for grinding steel because of the strong chemical affinity between the carbon in SiC and the iron in steel. cBN is produced under the trade name Borazon by the General Electric Company. It has 5000 of relative hardness. Borazon grinding wheels are used for hard materials such as hardened tool steel and aerospace alloys. Diamond wheels are generally used in grinding applications on hard, abrasive materials such as ceramics, cemented carbides and glass. It also occurs naturally with relative hardness is 7000.

Mostly, silicon carbide and aluminium oxide are always used in the laboratory and also in manufacturing industry. These two types of abrasive are suited to different materials as we can show in Table 2.1 below (S. Malking and C. Guo, 2008).

Table 2.1: Types of abrasive wheel with suited materials

Type of abrasive	Materials
Silicon Carbide	- Gray and chilled iron - Aluminium and copper - Brass and soft bronze - Cemented carbide - Very hard alloys - Others
Aluminium Oxide	- Alloy steels - Carbon steels - Wrought iron - Hard bronzes - High speed stells - Annealed malleable iron - Others

The factors affecting the grain size, the grade of hardness, the structure and bonding materials are depends on the ductility of the material. It also can affect the results form when grind, so much better selected the suited abrasives when grind materials.

Abrasive particles and bonding material was consists in a grinding wheel. The bonding material in a grinding wheel holds the particles in place and then establishes the shape and structure of the wheel. These two ingredients, and the way they are fabricated; determine the parameters of the grinding wheel, which are: 1) abrasive material, 2) grain size, 3) bonding material, 4) wheel grade and 5) wheel structure (S. Malking and C. Guo, 2008).

In the grinding process, the preparation of grinding tools is the most important factor. Mechanical, thermal and chemical loads are applied to the grinding wheel during the grinding process. The wear is one of the effects these loads, where macro wear describes the deterioration of the macro geometry which consists of radial wear and edge wear. Conditioning is the veil in front of the grinding process since the condition of the grinding wheel severely influences the grinding result (K. Wegner, et al., 2011). Besides that, the rate of material removal depends upon the process variables such as wheel parameters, speeds, machine and coolant (R. Gupta, et al., 2000).

2.2.4 Grinding Wheel Dressing

S. Kalpakjian (n.d) mentioned that there are many types of wheel dressers used to dress the grinding wheel whenever it lost the shape and geometry such as diamond, dresser, and abrasive stick. The wheel dresser as we can see in the figure above is fixed into a magnetic table at a slight angle to the grinding wheel and driven by the contact with the wheel. Dressing is cutting the face of a grinding wheel to restore its original cutting qualities (J.S Calton, 2009).

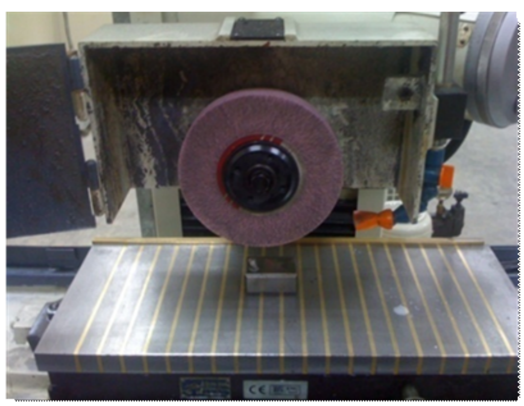

Figure 2.4: Position of dressing grinding wheel

To gain the desired grinding results, it is absolutely necessary to know the influence of the input parameters and their combinations on the dressing result (K.Wegener, et al., 2011).

Figure 2.5: Wheel Dresser

Mostly, in the laboratory this type of wheel dresser is commonly used to dress the grinding wheel. Dressing before and after grinding process is very important in order to get the best result and also can improve surface roughness.

2.3 COOLANT

Most grinding operations need coolant to keep the wheel surface clean and provide corrosion protection for newly machines surfaces. Coolant has a high thermal capacity, low viscosity, is low-cost, non-toxic, and chemically inert, neither causing nor promoting corrosion of the cooling system (J.F. Kellya and M.G. Cotterell, 2002). K.Wegener et al. (2011) and C. Heinzel et al. (1999) explained that the friction and wear associated with grinding process will reduce by using lubrication of grinding fluids. Furthermore, the coolant provides the required cooling of the grinding in order to prevent heat accumulation. This heat is formed by the friction that develops in the contact zones between the tool and work piece as well as between tool and chip. Heat generated may cause some burns in some cases, but it can overcome by using the coolant. Therefore, abrasives and work piece will incorporate a coolant to cool the work piece so that it does not overheat and go outside its tolerance (E. Mehmood, n.d).

Nowadays, mostly industry and research institutions are looking for ways to reduce the use of lubricants because of ecological and economical reasons. Some of benefits coolants improves machinability and also increase productivity by reducing the tool wear. The portion of the heat absorbed by coolants and the reduction of heat build-up due to lubrication depends strongly on the cutting process (J.F. Kellya and M.G. Cotterell, 2002).

In many precision machining processes such as surface grinding, coolant is typically used to provide functions such as lubrication and cooling in order to reduce surface grinding temperature (Y. Gao et al., 2003). Green cutting also can become environmental protection and ecological. Water vapor is cheap, pollution-free and ecofriendly. Therefore water vapor is a good and economical coolant and lubricant (J.Liu et al., 2004).

Better surface roughness would be observed by using cutting fluids in machining processes. The selection of cutting fluids for machining processes generally provides various benefits such as longer tool life, higher surface finish quality and better dimensional accuracy. These results also offer higher cutting speeds, feed rates and depths of cut. The product of machining process will be much higher with combination of selecting higher machining parameters (O. Cakir et al., 2007). Every coolant consists of a basic fluid, to which are added other products such as anti-wear, anticorrosion or emulsifying agents (E. Brinksmeier et al., 1999).

2.3.1 Water Based Coolant

In our real life, water is not only important for natural ecosystems and sustaining human communities, but also important for raw material in industry. Every production process uses water for some purposes such as for washing, cooling, fabricating, processing and others.

E. Brinksmeier et al. (1999) explained that coolant for metal working processes can be divided into three which are oil-based coolant, additives and water-based coolant. Oil-based coolant normally consists of 80- 95% basic oil. It can be divided into four groups which are; 1) basic oils without additives, 2) basic oils with chemically active additives, 3) basic oils with surface active additives, and 4) basic oils with chemically active additives and EP-additives.

Water based coolant can be divided into two groups which are water- based solution and water-based emulsion. Water-based solutions consist of inorganic and/ or organic substances while water-based emulsion concentrates contain 20-70% basic oil. Common oil concentrations in emulsions for grinding operations are between two and 15%. Water based coolants contain up to 20 components in which, each of the components can themselves be multi- component mixtures (E. Brinksmeier et al., 1999 and J.F.G. Oliveira1 and S.M. Alves, n.d).

Besides that, water can divide into three types of particle substances which are liquid, gas and solid. It also has several unique properties. For example, water has a high specific heat, so it can absorb a large amount of heat energy before it can hot. Water also can conduct heat easily compared to any liquid excluding mercury.

2.4 EFFECT OF OTHER PARAMETERS ON SURFACE ROUGHNESS

2.4.1 Wheel Speed and Table Speed

Many variables contribute to the ground surface texture as summarized in Figure 2.6 below.

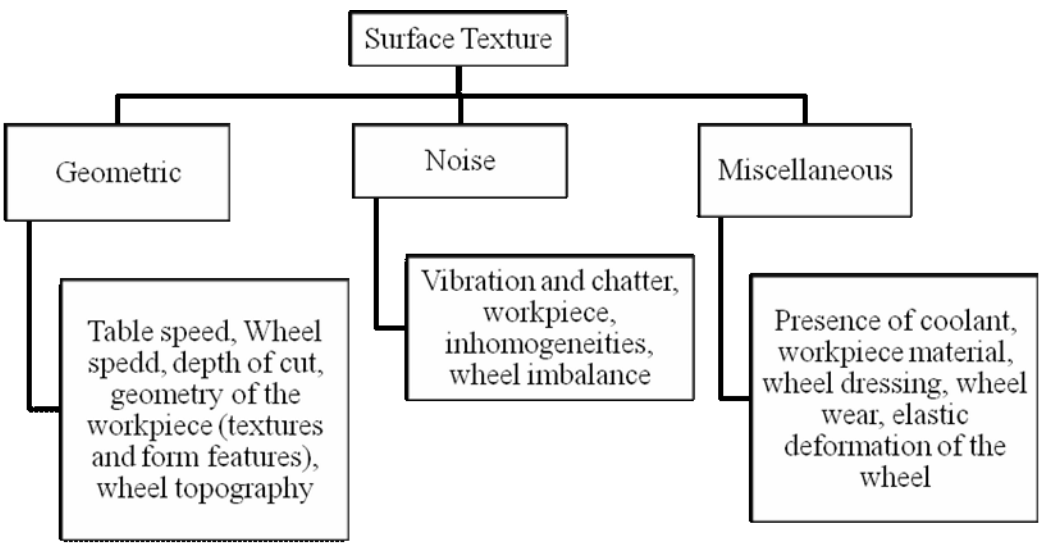

Figure 2.6: Classification of factors affecting the ground surface texture

Source: E.J. Salisbury,K.V.Domala, K.S. Moon,M. H. Miller, J.W. Sutherland, 2011

The geometric factors include the cutting parameters such as wheel speed and table speed, work piece geometry including initial surface texture and form errors, and grinding wheel topography characteristics such as grit size, wheel dressing and wear. The noise factors are disturbances in the grinding environment and are not always significantly involved in the cutting process.